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MEASUREMENT OF ANGULAR AND LINEAR ACCELERATION SENSITIVITIES OF THE ENDEVCO MODEL 7302 ANGULAR ACCELEROMETER

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As the measurement techniques used in the calibration of the 7302 Angular Accelerometer are described, the characteristics of this new product will be introduced.

As with most accelerometers, it is a spring-mass system in which the sensing element is associated with the spring. This device is unique in that its mass is a fluid and the sensing element is a piezoresistive pressure transducer. The internal geometry causes the fluid to respond to angular accelerations about the axis of the transducer. It is therefore a single axis piezoresistive angular accelerometer, with a frequency response of an underdamped single degree of freedom system, (see Figure 1).

Using this transduction mechanism, the normal trade-off between sensitivity and frequency response occurs: to make its resonant frequency higher, the sensing element must be stiffer, which decreased sensitivity. The configuration chosen for the 7302 is such that resonant frequency is about 2300 Hz, and sensitivity is about 6 microvolts per radian per second squared (given a 10V excitation).

The measurements of sensitivity to angular motions will be described first. In general it is easier to create pure angular motions (without linear motion of the center of rotation), than it is to create a linear motion without accompanying rotation.

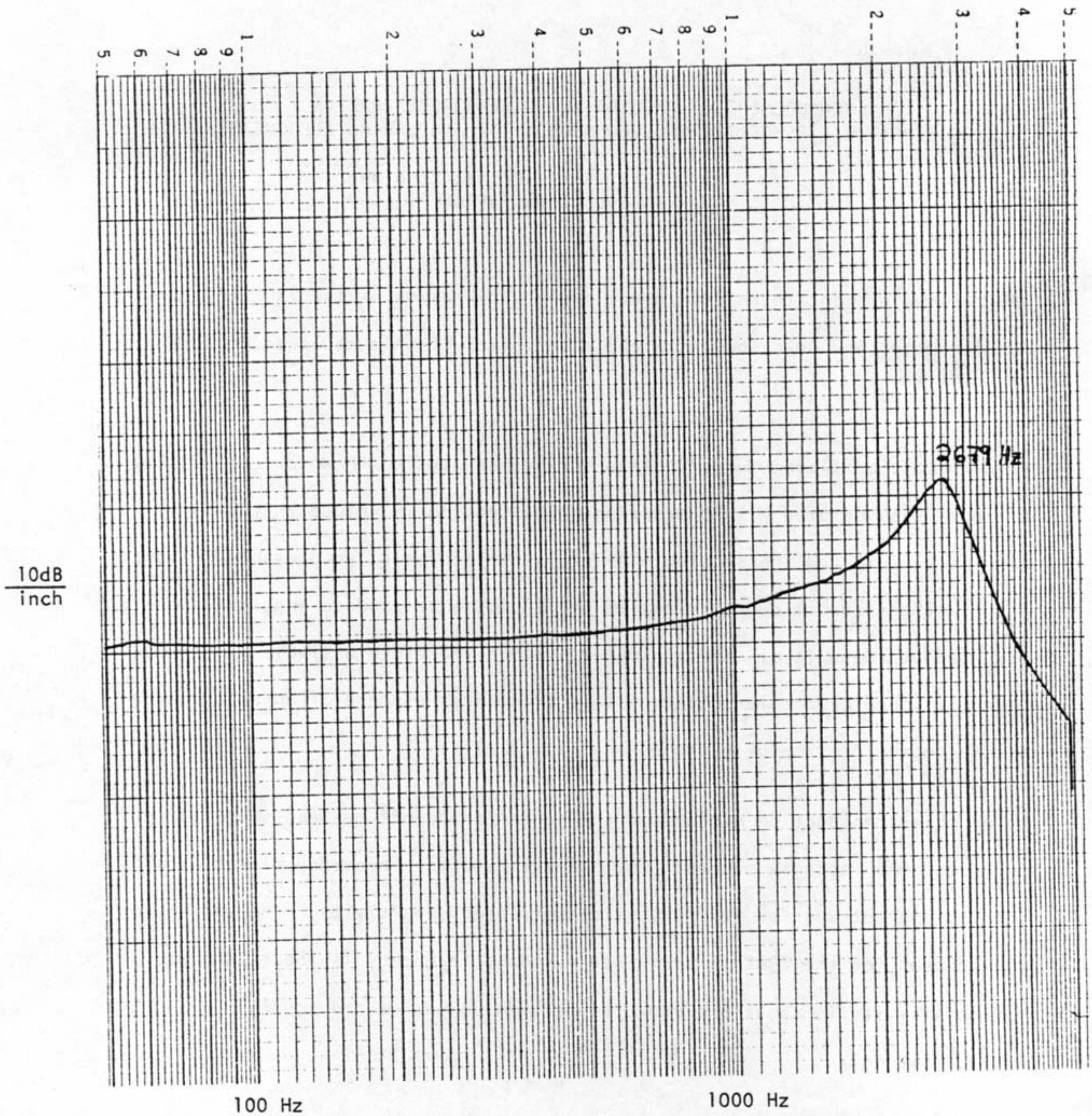

FIGURE 1 - 7302 Frequency Response to Angular Acceleration

The sensitivity to angular accelerations is measured with the system depicted in Figure 2. To study the primary sensitivity, the transducer is placed on the mounting platform, coaxial with the shaft of the dc motor. With an ac signal applied to the motor, the shaft vibrates in an angular manner, monitored by the linear accelerometer mounted tangentially on the platform. Knowing its sensitivity and distance from the shaft axis, the applied angular acceleration amplitude is derived. A complete frequency response, such as in Figure 1, can be performed with this system. Absolute techniques have been used to verify the results, one using optical measurements, another with a dual spin axis rate table. The system of Figure 2 is used due to its simplicity and accuracy.

Sensitivity to the two angular cross axes is obtained with the right-angled fixture shown, which orients the transducer axis at 90° to the shaft. The transducer is rotated about its axis to find the position of maximum cross axis sensitivity. This value is typically 0.5% of primary axis sensitivity for the 7302. It is the inherent symmetry of the internal geometry, as well as the homogeneity of the fluid, which allows such a low value.

When making this measurement, actual output was somewhat larger because some portion of the output was due to misalignment of the fixture. The misalignment caused a component of the acceleration to be parallel to the sensitive axis. A second measurement, made after a 180° rotation of the transducer about its axis, allowed determination of the magnitude of misalignment so that arithmetic cancellation of that component was possible.

Similar techniques were used when sensitivity to linear accelration was measured. As mentioned before, it is difficult to supply pure linear acceleration. Even the best electromagnetic shakers rock as they move, so it was

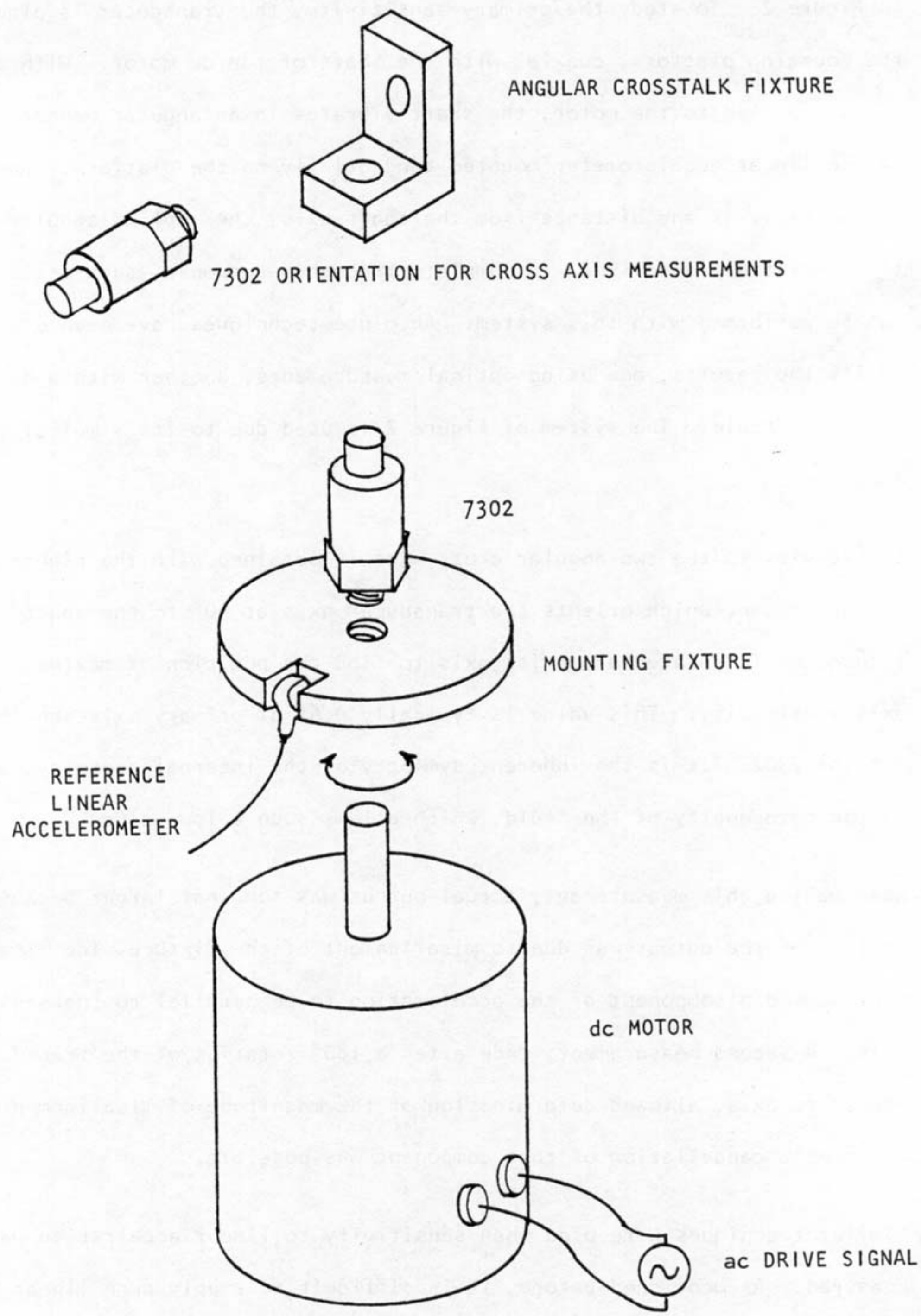

FIGURE 2 - ANGULAR SHAKER IN EXPLODED VIEW

necessary to use similar cancellation to separate the effects of angular and linear accelerations.

The results are shown in Figure 3, in which the Z axis refers to linear sinusoidally-varying accelerations parallel to the transducer axis, and the X-Y axes are those induced when the right-angled fixture shown in Figure 2 was used on the shaker. Note that in each case sensitivity is dependent on frequency. This result, as well as the fact that response is different in the two orientations, is understood.

First of all, remember that any linear acceleration will cause a pressure gradient to form in the fluid. Given that the sensing element of the 7302 is a pressure transducer, these pressures could cause signals, that is, crosstalk, if they are not cancelled. Again, it is the symmetry of the design which allows cancellation of the pressures, and hence, the amplitude of the signals is very low (on the order of microvolts per G). The physics of this design dictates that the shape along one axis be less symmetric than the other two, causing greater sensitivity in that axis. The 7302 was designed to have its greatest linear acceleration sensitivity along the transducer axis. For linear accelerations perpendicular to the transducer axis, the X-Y axes, internal symmetry is considerably better, resulting in linear sensitivity which is exceedingly small at low frequencies.

The frequency dependence of both plots is also accounted for by the completeness of the cancellation of acceleration-induced pressures. Very simply, at higher frequencies the cancellation is less complete, that is, the effect of greater quantities of fluid in the vicinity of the sensing element is felt. And, at the transducer resonance, as expected, the sensitivity is considerably larger than at the lower frequencies.

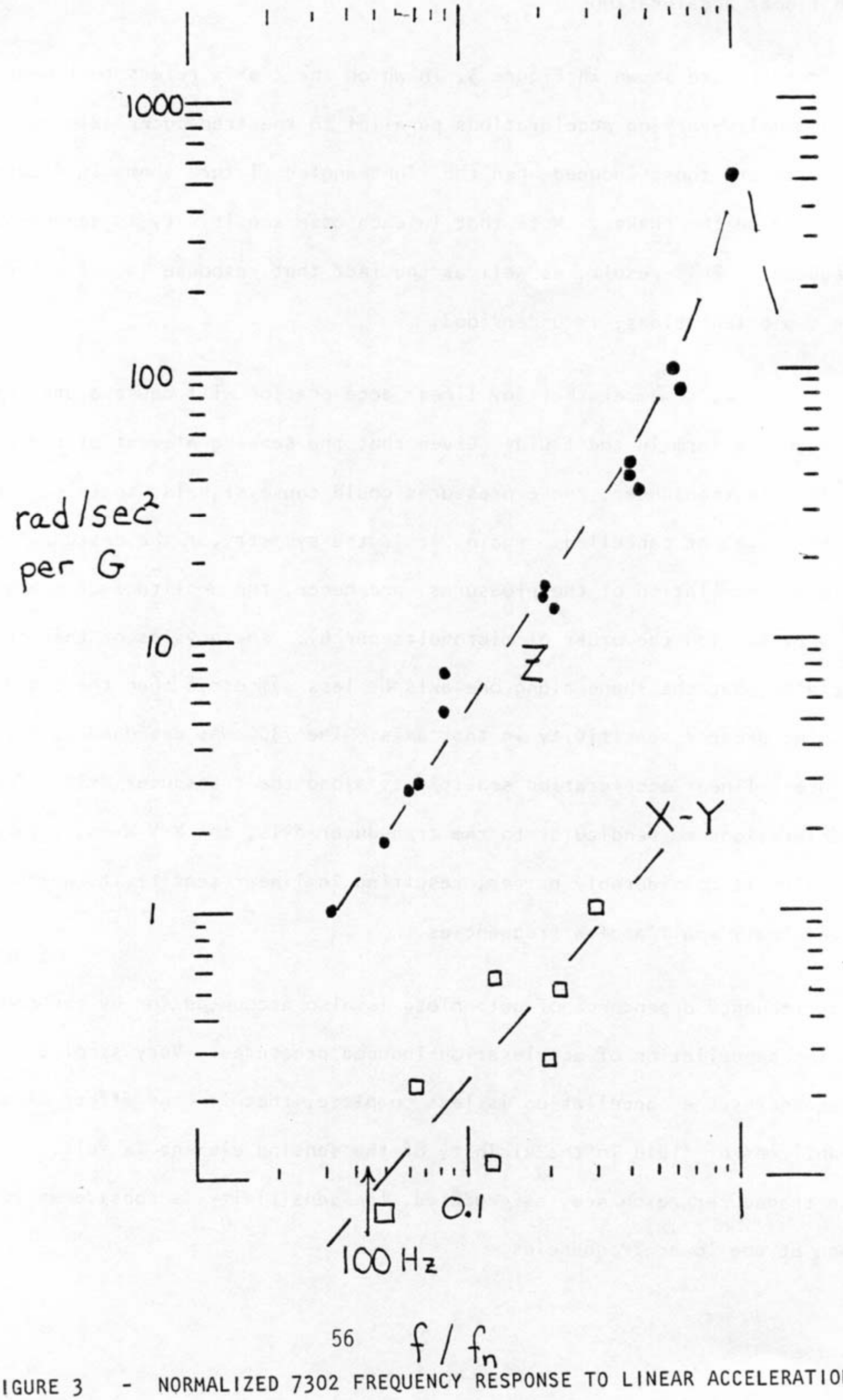

FIGURE 3 - NORMALIZED 7302 FREQUENCY RESPONSE TO LINEAR ACCELERATION

The transducer is underdamped, and these plots describe the fact that there will be some output given linear accelerations with high frequency components. Being underdamped, the accelerometer output could include the familiar ring-down. At higher frequencies, the response rolls off.

Not all shocks will cause this ringing. The left plot of Figure 4 shows a typical response of the 7302 subjected to a 96 G shock (the form of which is shown on the right) in a drop tower test. The response not only has no ringing, but shows that probably the anvil rocked at impact, causing both a positive and negative pulse.

If the 7302 is to be used in environments in which high frequency components are expected in the acceleration signature, three precautions are suggested: (1) prefilter the signal to remove outputs at the resonant frequency, and/or (2) keep amplifier gain down to avoid saturation, and/or (3) use digital filtration techniques in data processing.

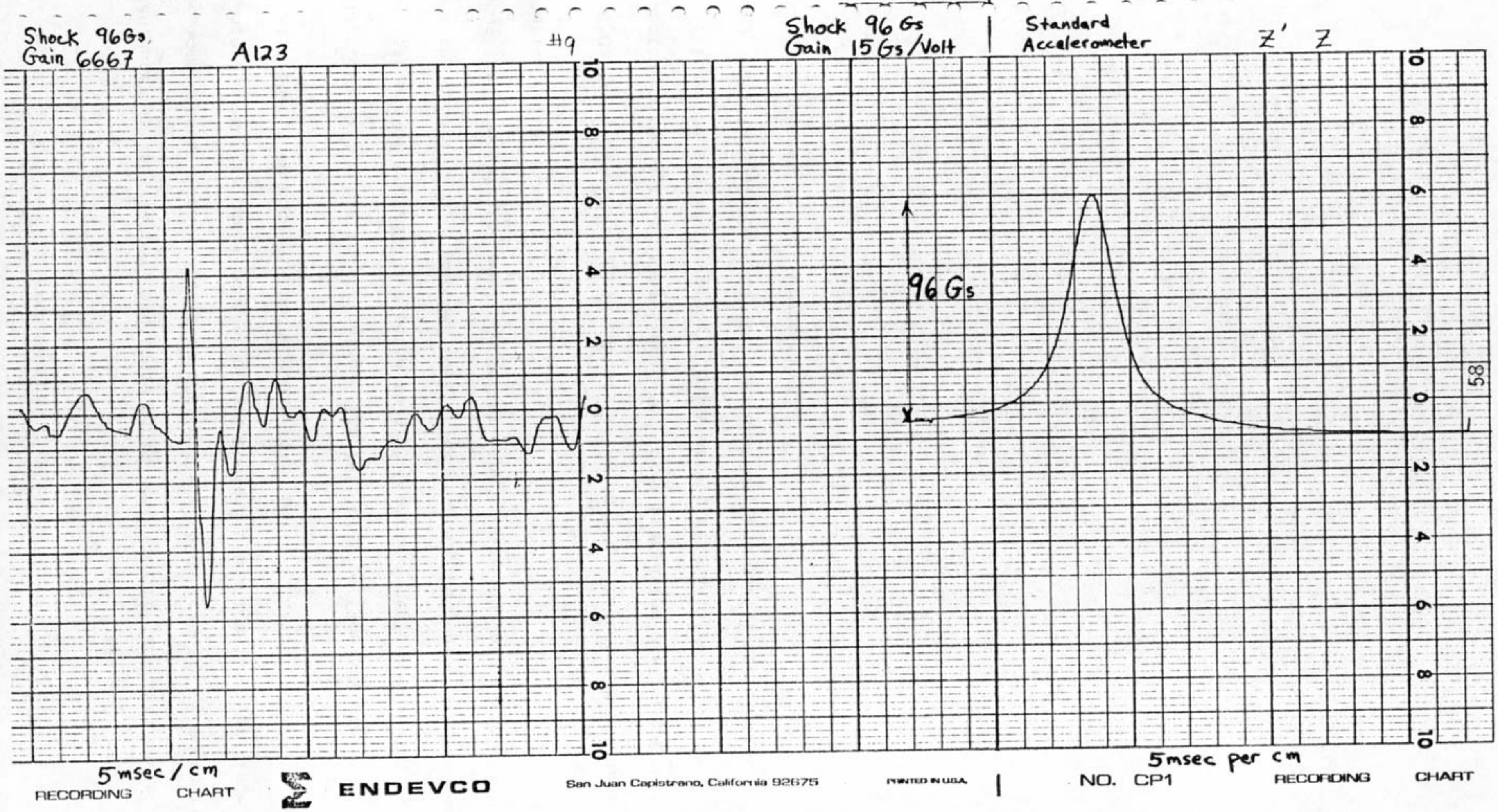

FIGURE 4 - 7302 RESPONSE TO 96G SHOCK (X-Y ORIENTATION)